Vitalizing biology instruction...

Boston University

School of Education

VITALIZING BIOLOGY INSTRUCTION

A LABORATORY-WORKSHOP APPROACH

Service Paper

Submitted by

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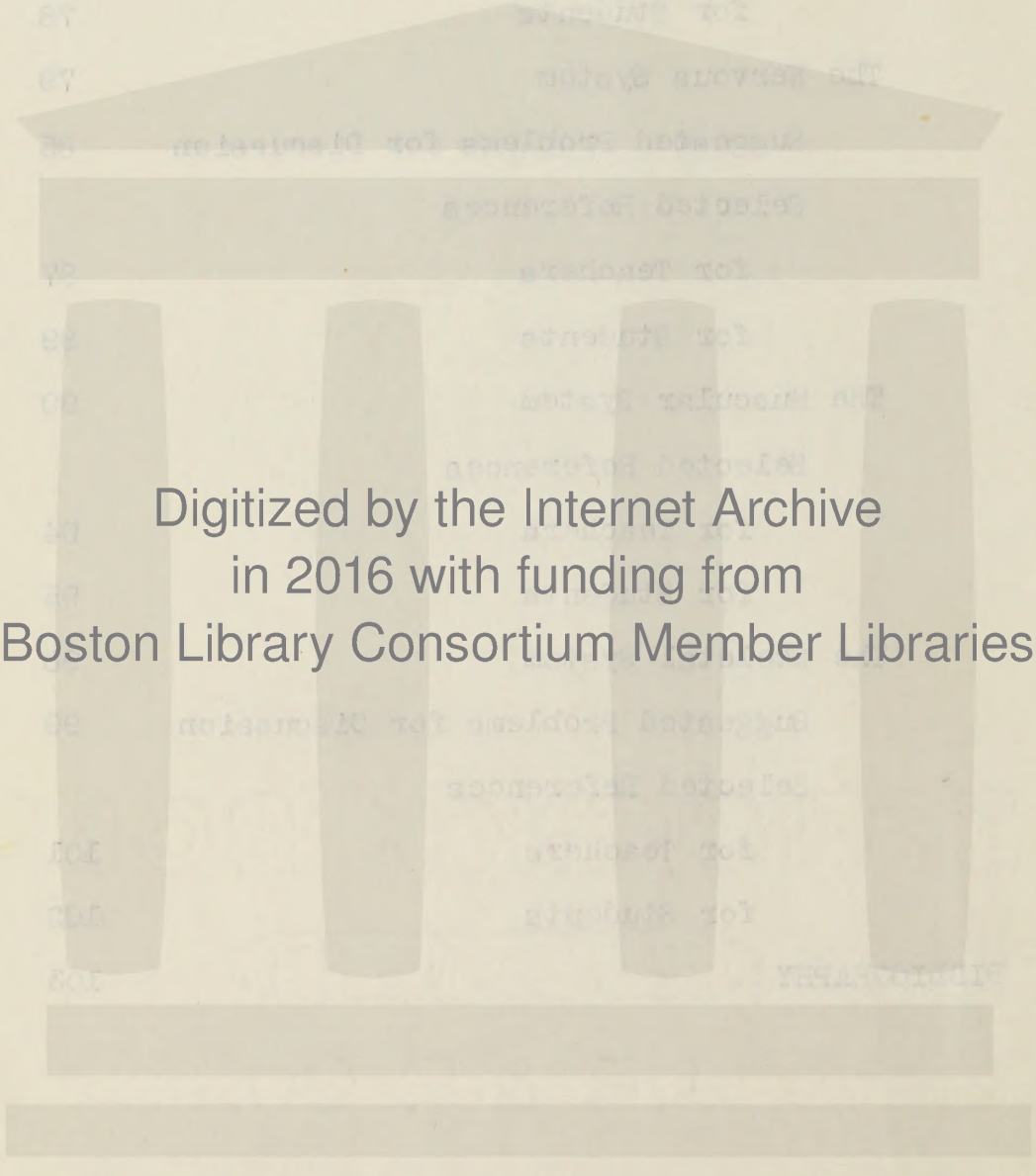

CHAPTER 1

INTRODUCTION

A - The Problem Stated

The premise presented in this paper has been developing over several years. My own experience as an undergraduate and as a teacher of biology pointed up a situation which impressed me as meriting attention. This situation in its entirety includes all that pertains to commonly accepted methods of teaching biology. Instructors who have taught two sciences, one of them being biology, are aware of the difference in classroom atmosphere, in pupil interest, and in results achieved. Briefly, biology has been a relatively dull and tiresome subject. My contention is that the teaching of biology can be vitalized and that a proper presentation will result in pupil interest, pupil intellectual curiosity, pupil participation, and scientific method of thought.

That an unsatisfactory situation in the teaching of biology does exist and that an entirely new approach is necessary for effective teaching is an opinion supported by the considered judgments of leading educators.

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That an unsatisfactory situation in the teaching of biology does exist and that an entirely new approach is necessary for effective teaching is an opinion supported by the considered judgments of leading educators.

That the method of vitalizing biology instruction presented in this paper is in line with the most modern concepts of science education is a proposition supported by the most eminent authorities.

It is held in this paper that lectures and recitations, supplemented with laboratory work, should be supplanted by a laboratory workshop approach to the teaching of biology. It is held that the student should go directly into the laboratory, spend all his time there, and acquire an actual firsthand experience which would cause him to request instruction. This instruction would be personal, individual, on-the-spot and motivated by the pupil's desire to deal with his immediate laboratory problem.

Because the anatomy and physiology of the frog so closely parallel the anatomy and physiology of the human being that to comprehend one is to understand the other, and because of the availability of frogs for laboratory purposes, it has been deemed expedient to concentrate pupil research on the study of frogs. The frog affords opportunity for complete coverage of the six systems necessary for a complete grasp of biological concepts.

The three propositions indicated above require proof. In support of these the following evidence is

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submitted: In the Harvard Report it is stated:[1] "Many students who expect to go to college are now offered an almost wholly verbal type of preparatory training while hand training and the direct manipulation of objects are reserved for the vocational fields. This is a most serious mistake." To further implement this view, the Report has this to say:[2] "The thought that an understanding of science might be conveyed as well or better without direct observation and experiment.....involves a fundamental misapprehension of the nature of science." For evidence that might serve to point up the problem as herein defined, and to support the position adopted by this paper, the Report is summoned again:[3] "From our point of view science is primarily a distinct type of intellectual enterprise, involving highly restricted aspects of reality and prepared as such to make particular types of contributions to general education. Its prime end is knowing rather than doing, or better still- it is doing in order to know."

1/General Education in a Free Society. The Report of the Harvard Committee. Cambridge, Mass.: Harvard University Press, 1945. p. 267.

2/ibid., p. 153.

3/ibid., p. 161.

Need one seek further for proof and support for the approach as contemplated here? What more categorical support could be demanded? In deference to any trace of scepticism yet remaining, a comment noted in The Seventh Yearbook is apropos. Citing the need for more laboratory experience and for the opportunity to inculcate scientific thinking in a more acceptable environment than now obtains in secondary school biology, the Yearbook states:[1] "To present live content that is on the level of the child's.....ability is necessary if interest is to be maintained and finer appreciations developed." So much for the statement of the problem.

B. Considerations Affecting the Solution of the Problem

"The final aim of modern education is adjustment of the individual to the changing needs of an evolving society."[2] Education, then, must prepare the individual so that he is equipped to cope intelligently and successfully with the neverending complex problems constantly arising to test him. In a word, each person must be taught to think - to observe and evaluate data, and to

1/The Seventh Yearbook of The Department of Classroom Teachers. Washington, D.C.: 1932. The Department of Classroom Teachers of the National Education Association of the United States. p. 139.

2/Wolcott, R., Animal Biology. 2nd ed. New York: McGraw-Hill Book Co, 1940. Preface, p. 1.

reason from facts.

The average biology class operates on a mass-production basis. The class functions as a unit comprising some 30-40 students. Notwithstanding that The Laboratory-Workshop Approach is also organized and operated on a class basis, it provides that pupils work in pairs or groups. Each unit is responsible for its own specimen, which becomes its exclusive property. The feeling of ownership might well promote and encourage a more active and sincere interest on the part of the student. Thoughtful handling of the specimen must demand that the pupil seek instruction in scientific techniques, dissections, and care and handling of instruments. In the words of the Harvard Report:[1] "Science instruction primarily takes the form of conveying some familiarity with the world of immediate experience, and this necessarily proceeds by direct contact and emphasis on fact and classification."

The principle of re-allocation of time to provide more emphasis on laboratory work is a means more satisfactorily and effectively to indoctrinate the student with scientific methods as a modest first step. He must be taught to draw tentative conclusions subject to later

1/General Education in a Free Society. The Report of the Harvard Committee. Cambridge, Mass.: Harvard University Press, 1945. p. 157.

revision. In a word, serious effort must be made to set the student on the road to scientific thinking; to protect him against 'slogan thinking', to give him some concept of the difficulties of approaching truth - to see to it that he appreciates the difficulties confronting scientists in their laboratory quest for truth. To put it another way, the student must have an opportunity to appreciate scientific attitudes in tune with the times. The position is taken that the approach embodied here offers an excellent means to this end at the secondary level. At this level the type of thinking generally encountered in the classroom is not calculated to bridge the gap between the layman and the scientist. But since the modern pupil will be living in a scientific age he must be prepared to think in terms peculiar to it. Instruction intended to encourage scientific thinking should seek it as an important by-product of laboratory activities.

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In football the student is directed to the playing field. Here he is permitted to toss and kick a ball around at will. He soon seeks expert advice on the proper procedures and techniques. He desires to master the art of football playing - hence he seeks expert guidance. His ignorance of the proper methods demands it. So, too, in the realm of biology - the student is instructed in scientific principles and techniques at his own behest. Here again he has come face to face with a problem that interests him but whose solution eludes him because he lacks the correct knowledge. It seems superfluous to point out that coaches spend very little time, comparatively, on 'skull practice'. Football is played on a field. Thus it is taught and learned there. Why not apply this technique to biology? This contention is supported by an opinion in the Harvard Report:[1] "The difference between courses and activities is apt to correspond in the student's mind to the differences between duty and pleasure."

The literature abounds in objective evidence to justify and indeed insist upon personal activities by the student of biology. One such earnest recommendation is

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[1]The Harvard Report, op. cit. p. 187.

that of Calkins:[1] "Man has always been interested in the subject (biology) as offering some possibility of an interpretation of himself. He has studied and dissected every new type of living thing that he has found; he has compared the structures and their functions with those of organisms which were already known...." He states further that the morphology and physiology of living things indicate that:[2] "....all animals are fundamentally alike rather than fundamentally different."

It is with the latter thought in mind that the frog is considered to be an efficient vehicle for the study of biology in secondary schools. Then, too, Wolcott holds that:[3] "Man as the highest of animals can learn by the study of animal life the principles of effective living." The Harvard Report also states:[4] "The observation that part for part the structure of man parallels that of the frog conveys as can no amount of statement a sense of....relationships of living organisms."

1/Calkins, G.N., The Smallest Living Things. New York: The University Press, 1932. p. 2.

2/ibid., p. 3.

3/Wolcott, R., Animal Biology. 2nd ed. New York: McGraw-Hill Book Co, 1940. p. 3.

4/The Harvard Report, op. cit. p. 151.

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4/The Harvard Report, op. cit. p. 151.

This sense of relationship demands a laboratory approach for its realization. No other method of presentation can be efficacious and satisfactory.

With regard to the importance of shop training in general education, the Harvard Report has this to say:[1] "For those who intend to go into scientific or technological work it has special relevance. The manipulation of objects, the use of tools, and the construction of simple objects are required for entry into the world of experimentation." The Report says pointedly:[2] "What students should learn in secondary schools specifically is the use of simple tools in the execution of simple basic operations." In a publication entitled, "Venture in Public Health Integration", one reads:[3] "The truth must be effectively implemented with techniques of behavior." This thought is in line with the considered opinion of Dr. Billett who states:[4] "Education is guided growth. The pupil's activities are given direction only by some goal he seeks to attain." Mastery of the frog as here presented is believed tenable as a means to

1/ The Harvard Report, op. cit. p. 173.

2/ ibid., p. 173.

3/ Venture in Public Health Integration. New York: Columbia University Press, 1947. p. 12.

4/ Billett, Roy O., Fundamentals of Secondary-School Teaching. Boston: Houghton, Mifflin Co, 1940. p. 174.

Dr. Billett's objective as well as providing an opportunity under teacher guidance for the pupil to learn about himself. What are the inevitable concommitants of this solution of our problems?

The Laboratory-Workshop Approach proposes to provide four or five periods per week in actual laboratory exercises. Normal lecture-recitation formulae are omitted. The teacher's role need not change, but his activity will be pupil-initiated as the latter works at solving his problems. Burton states the theme succinctly and accurately when he says:[1] " The learning process proceeds best when the numerous activities are unified around a central core or purpose; when the learner identifies himself with the purpose through originating and accepting it." The central core or purpose in this instance would be mastery of the frog and the concommitant studies which stem from it. Burton states further that a learning situation such as is described above will bring about a transfer of learning.[2]

To obviate the criticism that the student is 'turned loose' as it were, in the laboratory to fumble around until he finds something to excite queries, it

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1/Burton, W.H., The Guidance of Learning Activities. New York: Appleton-Century Co, 1944. p. 212.

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1/Burton, W.H., The Guidance of Learning Activities. New York: Appleton-Century Co., 1944. p. 312.

2/Ibid., p. 312-14.

must be stated that a brief pre-talk is always necessary. General objectives as well as specific rules and directions must be laid down in advance for any group. Thus more time is allowed for pupil participation in learning activities and more time is permitted the teacher for individual instruction and guidance. A more pleasant and friendly atmosphere should derive. Where interest in the work is aroused spontaneously and from within the pupil, fewer serious behavior problems result. Another signal advantage deriving naturally from this type of laboratory approach is that every pupil may participate up to the level of his own abilities. There need be no set standard of performance. The course is so designed that ample latitude is provided for the superior student, who may possibly complete all six systems of the frog: digestive, circulatory, respiratory, nervous, muscular, and skeletal. His less gifted classmate, working at a pace consistent with his natural abilities, may conceivably complete only the circulatory system. It is maintained, however, that the latter has the opportunity to benefit by attaining all the desirable end-results achieved by his more gifted companion. In fact, the slower student may experience a new motivation in the realization that he is considered to be on the same level as his classmates, since he can set his own

goal - one capable of realization.

A laboratory course intended to satisfy the demands outlined above must be very carefully designed. Obviously it must be a blend of object-handling, observation, data collection and recognition of perplexities requiring on-the-spot teacher assistance. Such a course can be no mere following of a laboratory manual. Rather, it must be meticulously constructed, graded and articulated in the light of pedagogical and scientific requirements. Only thus can we happily marry technique and theory; scalpel and question; only thus can we anticipate and provide for a series of teaching situations. In the actual workshop material now presented it will be noted that there is a recognition in terms of integration that new objectives inherently demand new procedural approaches.

CHAPTER II

LABORATORY-WORKSHOP DIRECTIONS AND EXERCISES

Subphylum Vertebrata

Class: Amphibia Order: Salientia

A FROG [1],[2],[3],[4],[5]

Place the animal in a dissecting pan and observe its form and color. The body is short and compact, with a large head and mouth; the hinder end is characterized by the lack of a tail, and by the great length of the hind legs. The color is such as to adapt it to the environment in which it lives, and may change from time to time, like that of a chameleon, although not to the

1/Chidester, F.E., Zoology. New York: D. Van Nostrand Co. 1932. pp. 265-275. passim.

2/Dickerson, M., The Frog Book. New York: Doubleday, Doran. 1906. passim.

3/Hegner, R.W., College Zoology. New York: Harper and Bros. 1936. pp. 364-425. passim.

4/Parker and Haswell, A Textbook of Zoology. Vol. 2. Boston: The MacMillan Co. 1940. p. 245, et. seq.

5/Wright, A. W., and A. H., Handbook of American Natural History. Vol. 1. Handbook of Frogs. New York: The Comstock Publishing Co. 1933. pp. 179-196. passim.

same extent as in that animal.

The skin of the frog is without scales, claws or other hardened integumentary structures, such as are possessed by other vertebrates. It is, however, provided with numerous integumentary glands which secrete a protective slime.

The body of the frog may be divided into two regions, the head and the trunk. The neck region, which is wanting in fishes and is so characteristic of land vertebrates, is just beginning to make its appearance in amphibians. A distinct neck is not present; there is present, however, one cervical vertebra with which the skull articulates. The caudal region is also wanting in the adult. In the larval frog and toad a long tail is present, by means of which the animal swims; it is, however, gradually absorbed as the tadpole passes through its metamorphosis.

THE HEAD: This body division is triangular in shape. The mouth is large and bordered by skinny lips, which close tightly together like the cover on a box and thus prevent air from escaping during the act of respiration. The eyes are large and protruding. Each is protected by two eyelids, the upper one of which is large and thick with little power of movement; the lower one is semitransparent and movable.

In front of the eyes are the nostrils; each of these is provided with a valve which can be tightly closed. The nostrils communicate directly with the mouth. Probe them with a bristle. Back of each eye is a large, circular area, the tympanic membrane, or ear drum which is thus on the outer surface of the body. Between the eyes is a small, dark spot which marks the frontal organ; it is a rudiment of a median eye. In the male frog, of a certain species, a pair of large vocal sacs project from the hinder part of the head in the breeding season. Probe them from the mouth, and determine their extent.

THE TRUNK: This body division is short and shows externally no marks of segmentation; it bears the appendages. In the middle of the back will be noticed a prominent hump, which indicates the position of the sacrum, where the hinder appendages articulate with the spinal column. At the posterior end of the trunk and slightly dorsal in position is the small opening of the cloaca, the anus.

THE APPENDAGES: Two pairs of legs are present; each leg is made up of three divisions, a proximal, a middle, and a distal division. In the foreleg these correspond to the upper arm, the forearm, and the wrist and hand respectively; in the hind leg, to the thigh, the shank, and the ankle and foot. The toes have no

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claws.

The forelegs are relatively short and weak and do not aid in locomotion. Four fingers are present, the thumb being rudimentary. In the male frog the first finger is thickened. The fingers are not joined by a web.

The hind legs are long and muscular and are the principal organs of locomotion both on land and in the water. While the animal is at rest the hind legs are folded together back of it in a position ready for springing. In this position the three divisions of the leg become apparent. In the distal division certain ankle bones are much elongated and make this the longest of the three divisions. The five toes are webbed, the medial (innermost) one being the big toe.

Exercise:[1],[2] Draw a dorsal view of the extended animal showing the features above mentioned; carefully label all.

THE MOUTH AND PHARYNX:[3],[4] Open the mouth as wide

1/Baker, Mills, Connor, Dynamic Biology Today. New York: Rand-McNally Co. 1943. p. 139.

2/Kroeber and Wolff, Adventures with Living Things. Boston: D.C. Heath and Co. 1938. p. 63.

3/Burnet, M., A Laboratory Manual of Zoology. New York: American Book Co. 1908. p. 88.

4/Hegner, R. W., College Zoology. New York: Harper and Bros. 1936. p. 370.

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2/ Kroeber and Wolff, Adventures with Living Things. Boston: D.C. Heath and Co. 1939. p. 80.

3/ Burnet, K., A Laboratory Manual of Zoology. New York: American Book Co. 1938. p. 80.

4/ Regner, R. W., College Zoology. New York: Harper and Bros. 1939. p. 370.

as possible; cut each angle of the jaw a little; if necessary, so that the mouth will remain open. The mouth and pharynx will be seen to be a single space which extends back to the beginning of the oesophagus. With forceps pull the tongue forward; it is a slimy bandlike structure which is attached only at its forward end. Behind, it extends back into the pharynx where it is bilobed. The lower jaw is without teeth. Just back of the tongue in the floor of the mouth may be felt the hyoid cartilage, which supports the tongue.

Back of the tongue is the glottis, a median, longitudinal slit which opens into the lungs. The glottis is in the middle of an elliptical elevation formed by the two arytenoid cartilages; it is usually closed, but may be opened with a needle.

The frog has two methods of respiration:[1] (1) with the skin and the mucous membrane of the mouth and pharynx, and (2) with the lungs. Air is taken by regular inspirations through the nostrils into the mouth and pharynx, where it is acted upon by the highly vascular (mucous) membrane. It is also at irregular intervals taken by an act of swallowing through the glottis into the lungs. It

1/ Chidester, F. E., Zoology. New York: D. Van Nostrand Co. 1932. p. 285.

is expelled from the lungs by the elasticity of their walls, which contain muscle fibers, and that of the muscular sides of the body. Immediately after the expiration air is again swallowed, so that the lungs are kept filled. The floor of the mouth will be observed in the live frog to oscillate rapidly and regularly. This act is not connected directly with the pulmonary but rather with the pharyngeal respiration.

The opening behind the glottis into the digestive tract is the gullet, or the oesophagus. Probe it. In the roof of the mouth note the upper jaw, in which is a row of teeth called the maxillary teeth. Just behind them in the foreward part of the mouth, near the median line, are two small groups of teeth called the vomerine teeth. On each side of these is one of the inner openings of the nostrils. Probe them. Near the angle of the mouth on each side is the large opening into the tympanic cavity, the Eustachian tube. Probe one.

Exercise:[1] Draw a sketch of the opened mouth and pharynx on a scale of about 2" and carefully label all the organs mentioned above.

1/Gruenberg and Bingham, Biology and Man. Boston: Ginn and Co. 1944. p. 211.

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1/ Oruenberg and Stephens, *Biology and Man*. Boston: Ginn and Co. 1964. p. 311.

THE INTERNAL ORGANS:[1,2] Place the animal on its back in a dissecting pan, with its head away from you, and pin it fast with a large pin through the tip of the jaw and one through each of the four legs. Raise the skin of the belly with forceps, and with scissors make an incision in it along the midventral line the entire length of the body.

Notice the looseness of the skin and the large space between it and the underlying muscles. This space is a lymph cavity. Note carefully the points where the skin is attached to the muscles. Note the large blood vessels on the inner side of the skin; these are the cutaneous veins and arteries. The blood is brought to the skin to be aerated, an important part of the respiration being carried on through the skin of the animal.

Through the semitransparent muscles in the region of the forelegs may be seen and felt a number of plate-like bones and cartilages. These form the pectoral girdle and the breastbone, which support the forelimbs. In the midventral line will be seen through the body wall

1/Colton, Buel P., Zoology, Descriptive and Practical. Boston: D. C. Heath and Co. 1903. pp. 84-86. passim.

2/Hegner, R. W., College Zoology. New York: Harper and Bros. 1936. pp. 369-370.

a broad, dark line; it is the abdominal vein.

Lift up the ventral body with forceps and with scissors make a longitudinal incision through it in the median line the length of the body, taking care not to cut the organs lying beneath. Pull the two flaps of the body wall gently apart and pin them. Examine the organs which lie in the abdominal cavity but without disturbing any of them.

If the animal is a male or a female which is not breeding, the most conspicuous organs will be the large, reddish liver and the intestine. If it be a mature female, the dark-colored, granular ovaries may occupy a large part of the space within the body cavity; in this case the ovaries should be removed so that the other organs can be studied.

Lying on the left side of the liver and wholly or partly concealed by it is the elongated stomach. In front of the liver in the median line is the conical heart within its membranous pericardium. Lying between the lobes of the liver may be seen the small, greenish, spherical gall bladder.

Make a transverse incision in each flap of the body wall. Turn the flaps to the side and pin them down, exposing fully the internal organs.

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Make a transverse incision in each flap of the body wall. Turn the flaps to the side and pin them down, exposing fully the internal organs.

In addition to the organs already mentioned one

or both lungs may be seen. They are usually shriveled, saclike organs which lie at the forward end of the abdominal cavity, concealed by the liver. If either is full of air, it should be punctured and made to collapse. At the hinder end of the abdominal cavity, between the base of the hind legs, the large urinary bladder will be seen. Several elongated, yellowish bodies may be seen projecting from between the other organs; they are called the fat bodies.

The abdominal cavity is lined by a membrane called the perítoneum. Note that the organs in it are attached to the walls or to each other by thin membranes; these are the mesenteries; they are folds of the peritoneum.

Exercise:[1] Draw an enlarged outline of the animal and in it the internal organs as they lie in the body cavity before they have been disturbed. Label all carefully.

THE DIGESTIVE SYSTEM [2],[3],[4],[5]

This system consists of the mouth, pharynx,

1/Baker, Mills, Connor, Dynamic Biology Today. New York: Rand-McNally Co. 1943. p. 257.

2/Chidester, F. E., Zoology. New York: D. Van Nostrand Co. 1932. pp. 275-279. passim.

3/Curtis and Guthrie, Textbook of General Zoology. New York: John Wiley and Sons, Inc. 1938. pp. 25-36. passim.

4/Hegner, R. W., op. cit. p. 370, et. seq.

5/Newman, H. H., Outlines of General Zoology. New York: The MacMillan Co. 1925. pp. 272-274. passim.

oesophagus, stomach, intestine, cloaca, liver, and pancreas.

The mouth and pharynx have already been studied. Without cutting anything, press the liver to the animal's right and fully expose the stomach. It will be seen to be a large, curved organ, the anterior, or cardiac end being near the left lung at the side of the heart, and the posterior, or pyloric, end being near the median line of the body. The oesophagus is a short tube, not quite as wide as the stomach, which joins the cardiac end of that organ with the pharynx.

From the pyloric end of the stomach, which is marked by a constriction, the intestine proceeds, with many turns, to the hinder part of the body. It is composed of two divisions: the small intestine, and the large intestine, or rectum. The small intestine forms the greater part of it; its interior portion, the duodenum, is bent forward so as to lie parallel with the stomach, and between them lies the whitish, irregularly shaped pancreas. The rectum is about half an inch long and forms the hinder part of the intestine; it is much wider than the small intestine and may often be recognized by its dark color. The rectum is continuous posteriorly with the cloaca, a short, wide vessel which lies between the base of the hind legs and finds an outlet through

oesophagus, stomach, intestine, cloaca, liver, and pancreas.

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the anus.

Observe again the extensive mesenteries which bind the divisions of the digestive tract with the wall of the abdominal cavity.

At one side of the forward portion of the rectum will be seen a dark-red, spherical body, the spleen. Press the intestine and mesentery aside, -- but without cutting them, -- and observe the flattened, dark-colored kidneys, which lie close to the dorsal body wall. At their forward ends are two yellow, spherical testes if the animal is a male, or the irregular, saclike ovaries, if a female; in front of these organs are the yellow, finger-shaped fat bodies.

Observe closely the liver and pancreas. The former is composed of two main lobes, one of which is subdivided into two smaller lobes. Note carefully the connection, on the dorsal surface, between these two parts. Turn the whole liver forward, -- but without cutting anything, -- pin it there, and study its dorsal surface and the pancreas.

The pancreas is an irregular, whitish gland which lies in the bend made by the stomach and duodenum. Near the hinder border of the liver note the duodenum. It is a slender tube which issues from the stomach, passes behind the gall bladder and after receiving a number of

the anus.

Observe again the external mesenteries which bind the divisions of the digestive tract with the wall of the abdominal cavity.

At one side of the forward portion of the rectum will be seen a dark-red, spherical body, the spleen. Press the intestine and mesentery aside, — but without cutting them, — and observe the flattened, dark-colored kidneys, which lie close to the dorsal body wall. At their forward ends are two yellow, spherical testes if the animal is a male, or the irregular, ovarian ovaries if a female; in front of these organs are the yellow, finger-shaped fat bodies.

Observe closely the liver and pancreas. The former is composed of two main lobes, one of which is subdivided into two smaller lobes. Note carefully the connection, on the dorsal surface, between these two parts. Turn the whole liver forward, — but without cutting anything, — cut it there, and study its dorsal surface and the pancreas.

The pancreas is an irregular, whitish gland which lies in the bend made by the stomach and duodenum. Near the hinder border of the liver note the duodenum. It is a slender tube which issues from the stomach, passes behind the gall bladder and after receiving a number of

branch ducts from the liver, continues a short distance from the pylorus. It passes through the pancreas, from which it receives one or more small pancreatic ducts. Gently squeeze the gall bladder with forceps and force the dark-green bile into the duct; it will thus be easy to follow. If the bile will not flow, cut the gall bladder open and inject a carmine solution into it with a pipette.

> Exercise:[1] Make a semidiagrammatic drawing of the dorsal surface of the liver and pancreas, with an outline of the stomach and duodenum, showing the features just described; carefully label all the organs.

The study of the digestive system will be completed after the heart has been examined.

THE HEART AND ITS VESSELS [2],[3],[4],[5]

The heart of the frog is composed of five divisions: a single ventricle, two auricles, the sinus venosus, and

1/Curtis, Caldwell, Sherman, Everyday Biology. Boston: Ginn and Co. 1943. p. 342.

2/Burnet, M., A Laboratory Manual of Zoology. New York: American Book Co. 1908. pp. 90-92, passim.

3/Chidester, F. E., Zoology. New York: D. Van Nostrand Co. 1932. p. 279, et. seq.

4/Hegner, R. W., College Zoology. New York: Harper and Bros. 1936. p. 379, et. seq.

5/Newman, H. H., Outlines of General Zoology. New York: The MacMillan Co. 1925. pp. 275-279, passim.

the truncus arteriosus. Observe the pericardium, which closely invests the heart.

The ventricle is the large, conical, posterior portion of the heart; by its contractions the blood is sent forward through the truncus arteriosus, which is the large, cylindrical vessel springing from its anterior end. The truncus divides into two large vessels which pass forward and leave the percardial space. Each of these vessels then divides into three arteries, called the aortic arches, through which the blood is carried to all parts of the body. The anterior arch is called the carotid arch; it carries blood to the head. The middle arch is called the systemic arch. The right and left sides of this arch meet back of the heart and form the dorsal aorta, which lies just beneath the spinal column and distributes arterial blood to the trunk and extremities. The posterior arch is the pulmocutaneous arch; through it blood is carried to the lungs and the skin for aeration.

In front of the ventricle are the right and left auricle; they appear dark-colored in consequence of the thinness of their walls. On the dorsal side of the heart is a large, thin-walled, dark-colored sac, the sinus venosus. Blood is brought to the heart from the organs and tissues of the body by three large veins which enter

the truncus arteriosus. Observe the pericardium, which closely invests the heart.

The ventricle is the large, conical, posterior portion of the heart; by its contractions the blood is sent forward through the truncus arteriosus, which is the large, cylindrical vessel emerging from the anterior end. The truncus divides into two large vessels which curve forward and leave the pericardial space. Each of these vessels then divides into three arteries, called the aortic trunks, through which the blood is carried to all parts of the body. The anterior pair is called the carotid arch; it carries blood to the head. The middle pair is called the pulmocutaneous arch. The right and left sides of this arch meet back of the heart and form the dorsal aorta, which lies just beneath the spinal column and distributes arterial blood to the trunk and extremities. The posterior arch is the pulmocutaneous arch; through it blood is carried to the lungs and the skin for aeration.

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the sinus venosus: these are the right and left precaval veins, which enter the forward end of the sinus, bringing blood from the forward part of the body; and the post-caval vein, which enters the hinder end of the sinus, bringing blood from the hinder part of the body. From the sinus the blood enters the right auricle. Blood is brought to the heart from the lungs by the pulmonary vein, which lies alongside the left precaval vein and enters the left auricle; this vein is formed by the union of a right and a left pulmonary vein, which bring blood from the two lungs.

Exercise:[1],[2] Make a drawing of the ventral aspect of the heart and the blood vessels, so far as these have been observed.

THE DIGESTIVE SYSTEM: (Continued). Dissect this system in the following way. Lift up the liver with forceps and with scissors free its anterior border from the tissues beneath it, being careful not to injure the lungs. Find the oesophagus, which joins the stomach with the pharynx. Note that the lungs also join the ventral wall of the pharynx. Take hold of the oesophagus

1/Baker, Mills, Connor, Dynamic Biology Today. New York: Rand-McNally Co. 1943. p. 384.

2/Hegner, R. W., op. cit. p. 355.

which joins the stomach with the pharynx. Note that the lungs also join the ventral wall of the pharynx. Take hold of the oesophagus with forceps, lift it up, and with scissors cut across the floor of the mouth in front of the lungs.

The forward end of the digestive tract, with the lungs, being thus cut loose from the body, can be bent backward. With scissors cut the stomach and liver loose from the tissues beneath them; cut the mesentery by which the intestine is joined with the dorsal body wall, being careful not to injure the flattened kidneys and testes or ovaries, and straighten the intestine out. The entire digestive tract, together with the lungs, will thus be removed from the body, except at its hinder end. Extend and pin it, with the lungs attached to the pharynx, and the liver and pancreas attached to the duodenum by the bile duct.

Exercise:[1] Make a drawing of the digestive system, with the lungs; label all the parts and organs belonging to it.

Slit open the stomach and the forward end of the intestine and note the ridges on their inner surface. Cut open a lung and note that it is a hollow sac with a

1/ Curtis, Caldwell, Sherman, Everyday Biology. Boston: Ginn and Co. 1943. p. 342.

network of ridges on the inner surface.

THE UROGENITAL SYSTEM [1],[2],[3],[4]

The urinary and the genital organs are in close union with each other, notwithstanding their difference in function, and are conveniently studied together. The urinary organs consist of the paired kidneys, the paired ureters, the urinary bladder, and the cloaca.

The kidneys are two large, flattened bodies which lie close to the dorsal body wall in the posterior portion of the body cavity. The ureter is a straight white tube which runs from the outer posterior border of the kidney to the dorsal wall of the cloaca. The urinary bladder is a large, bilobed sac at the hinder end of the body cavity, which springs from the ventral wall of the cloaca. Its opening into the cloaca can be applied closely to the openings of the ureters and it can thus receive the urine from them; in it the urine is stored.

On the ventral surface of the kidneys is an ir-

1/Burnet, M., A Laboratory Manual of Zoology. New York: American Book Co. 1908. p. 90.

2/Gordon, A., An Outline of General Zoology. New York: Barnes and Noble. 1942. p. 159, et. seq.

3/Hegner, R. W., College Zoology. New York: Harper and Bros. 1936. p. 389, et. seq.

4/Parker and Haswell, A Textbook of Zoology. Vol. 2. Boston: The MacMillan Co. 1940. pp. 226-271, inc.

regular, yellowish line which is called the adrenal body, an endocrine body.

The genital organs consist of the testes in the male and the ovaries in the female, and the ducts which conduct the genital products to the outside.

THE MALE: The testes are two yellow, ovoid bodies which lie against the ventral surface of the kidneys and are attached to the dorsal wall of the abdominal cavity by mesenteries. Joining each testis with the ventral surface of the kidney are about a dozen fine tubes, which are suspended in the mesentery. Through these the spermatozoa, which are formed in the testis, make their way into the kidneys and thence into the ureter. This duct thus serves the double function of a ureter (an outlet for urine) and a sperm duct (an outlet for sperm) and is thus a urogenital duct.

THE FEMALE: The ovaries differ very much in size and appearance at different times of the year. In the springtime they are often so distended with the small, spherical ova that they may almost fill the abdominal cavity. If this is not their condition they appear as a pair of folded, dark-colored bodies which lie on the ventral surface of the kidneys attached to the dorsal body wall by median mesenteries. The paired ducts through

terior, yellowish line which is called the external body,
or epidermis body.

The genital organs consist of the testes in the
male and the ovaries in the female, and the ducts which
conduct the genital products to the outside.

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by mesenteries. Joining each testis with the ventral
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tions, which are formed in the testis, make their way
into the kidneys and thence into the ureter. This duct
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a pair of folded, dark-colored bodies which lie on the
ventral surface of the kidneys attached to the dorsal
body wall by median mesenteries. The paired ducts through

which the ova find their way to the cloaca are the oviducts. In adult females each of these ducts is a thick-walled, twisted tube which lies in the abdominal cavity against the dorsal body wall. Its anterior end opens into this cavity and is situated at the side of the heart and the posterior end opens into the cloaca. The posterior portion of the oviduct is expanded and forms a uterus, a reservoir for ova.

The ova escape from the ovaries by the rupture of their walls into the abdominal cavity. They then make their way to the mouths of the oviducts and through them into the cloaca. During this descent of the ova the albumin which surrounds them is secreted by the walls of the oviducts.

At the anterior end of the kidneys is a pair of prominent, yellow, branching fat bodies. They vary much in size at different times of the year, being largest before the breeding season and smallest after it.

While studying the urogenital system, the organs of which it is composed need not be disturbed. With a strong scalpel cut through the bony pelvis exactly in the median line between the legs in order to expose the cloaca. The urinary bladder is a delicate structure which is attached to the body wall by mesenteries. It must be freed from these and great care taken not to cut either

it or the cloaca.

Exercise:[1] Make a semidiagrammatic drawing of the urogenital system with the cloaca; label carefully all parts.

THE NERVOUS SYSTEM [2],[3],[4],[5]

This system is made up of the following divisions: (1) the central nervous system, which is composed of the brain and the spinal cord: (2) the peripheral nervous system, which is composed of (a) the paired cranial and spinal nerves and (b) the sympathetic nervous system; and (3) the special sense organs.

The cranial nerves and the spinal nerves each number ten pairs; the former spring from the brain and the latter from the spinal cord and place these structures in communication with the various organs and tissues of the body. The sympathetic nervous system lies in the body cavity in connection with the cranial and spinal nerves and innervates certain important viscera.

1/Gruenberg and Bingham, Biology and Man. Boston: Ginn and Co. 1944. p. 379.

2/Burnet, M., op. cit. p. 92, et. seq.

3/Curtis and Guthrie, Textbook of General Zoology. New York: John Wiley and Sons, Inc. 1938. pp. 60-85, passim.

4/Hegner, R. W., op. cit. p. 404, et. seq.

5/Parker and Haswell, op. cit. pp. 263-266, passim.

Remove the urogenital system from the body. Raise it carefully with forceps, and with fine scissors cut it loose from the dorsal body wall. Note the spinal column projecting into the body cavity, and lying ventral to it note a large blood vessel, the dorsal aorta; this must not be disturbed. The spinal column is made up of nine vertebrae and a long terminal bone called the urostyle. Identify them.

We shall study first the spinal nerves and the sympathetic system. Each spinal nerve is joined with the spinal cord by two roots, a dorsal and a ventral root, and passes out from the neural canal of the spinal column through a space between two vertebrae. At the point where these two roots meet, the dorsal root bears a large ganglion called the spinal ganglion. This ganglion is embedded in a prominent white body present between the vertebrae, called the calcareous body.

The ten pairs of spinal nerves will be seen in the body cavity, where they appear as white strands which lie against the dorsal body wall on each side of the vertebral column. The most conspicuous ones are the seventh, eighth, and ninth nerves, which lie close together in the hinder part of the abdominal cavity. They emerge on each side from between the seventh and eighth vertebrae, the eighth and ninth, and the ninth and the urostyle respectively,

and proceed straight back almost parallel with the spinal column. These nerves are joined with one another by short connecting branches and from a network, or plexus, called the sciatic plexus. From this plexus issue a number of nerves which proceed to the hinder quarters of the body and the hind legs. Of these the largest is the sciatic nerve, which goes to the hind leg.

Find the sciatic plexus. Follow the sciatic nerve into the leg as far as possible.

In the forward part of the abdominal cavity, on each side, is another much smaller nerve plexus called the brachial plexus, which is composed of the first three spinal nerves. Of these the second, which is the largest and most conspicuous, is a large white cord lying at right angles to the spinal column and emerging from between the second and third vertebrae; it is joined by a small branch from the first and one from the third spinal nerves, and passes to the foreleg. Find this plexus.

The sympathetic system consists of a pair of delicate longitudinal nerves which lie in the abdominal cavity on either side of the spinal column, close to the dorsal body wall. In each longitudinal nerve are ten enlargements, the sympathetic ganglia, from each of which one or more short branches run to a spinal nerve. Find these nerves and their ganglia.

THE BRAIN AND THE SPINAL CORD: In order to expose these organs remove the skin and muscles from the back of the head and trunk. Find the juncture of the skull with the backbone. By bending the head slightly down, a space about an eighth of an inch long, which is covered by a dark-colored membrane, may be made to appear between the skull and the atlas. Through the opening make a cut along the side of the cranium and with forceps lift off the roof of the skull, thus exposing the brain. Similarly cut through the two sides of the neural canal, which contains the spinal cord, and expose it.

Carefully remove the dark membrane, the pia mater, which covers the brain, and observe its five regions: the cerebrum, the diencephalon, the optic lobes, the cerebellum, and the medulla oblongata.

The brain and spinal cord are hollow structures. A delicate canal, called the central canal, runs through the center of the cord; in the brain this canal widens out into a number of spaces which are called the ventricles.

The anterior and largest region of the brain is the cerebrum. It is made up of two lateral hemispheres. Anteriorly, the ends of the hemispheres are fused and form the olfactory lobe, from the anterior end of which the two olfactory nerves pass to the nose.

Back of the cerebrum is the inconspicuous diencephalon, and behind that are the paired optic lobes, or midbrain. In the roof of the diencephalon will be seen, with the aid of a lens, several delicate structures, near the center of which arises a threadlike projection called the pineal body, which extends forward over the diencephalon.

Back of the optic lobes and separated from them by a deep groove is a narrow, transverse ridge, the cerebellum, and back of that is the medulla oblongata, which is continuous with the spinal cord. The dorsal wall of the medulla is a dark-colored, vascular membrane called the posterior choroid plexus, beneath which is the fourth ventricle of the brain. The triangular, depressed area which these structures form is called the fossa rhomboidalis.

The spinal cord is the portion of the central nervous system which lies in the neural canal of the spinal column. It is a thick, white band, oval in cross section, from which the paired spinal nerves spring. At two points it is swollen: (1) where the spinal nerves which form the brachial plexus, and (2) where those forming the sciatic plexus, respectively, leave it. The hinder end of the cord tapers rapidly until it becomes a fine thread which extends into the urostyle.

Study the lateral surface of the brain and the proximal portions of the cranial nerves. Ten pairs of these nerves are present in the frog; several pairs are so small, however, that they may not be seen by the unaided eye.

The first cranial nerve is the olfactory, which extends forward from the olfactory lobe. Cut away the roof of the anterior portion of the skull, and follow the two olfactory nerves forward. Each will be seen to branch a short distance in front of the olfactory lobe and be distributed to the walls of the nasal capsule.

Exercise:[1] Cut the olfactory nerves. Dissect away the left side of the skull and expose the left surface of the brain, preserving as far as possible the nerves which will be seen coming from it.

Lying close to the inner wall of the skull, at the hinder end of the orbit, is a yellowish body, often surrounded by a calcareous sac. This is the Gasserian ganglion, and must not be injured. Just behind the hemispheres the optic nerve, the second cranial nerve, issues from the ventral surface of the diencephalon and extends forward to the eye.

The third and fourth cranial nerves, the oculo-

1/Wolcott, R., Animal Biology. 2nd. ed. New York: McGraw-Hill Book Co. 1940. p. 376.

motor and the trochlear, are very small and can hardly be found; they go to muscles of the eyeball. The oculomotor springs from the ventral surface of the midbrain, the trochlear from the dorsal surface between the optic lobes and the cerebellum.

The fifth, sixth, seventh, and eighth cranial nerves, which are the trigeminal, abducens, facial, and auditory, respectively, arise close together from the forward end of the medulla oblongata. The first three of these nerves, together with the anterior end of the sympathetic nerve, are united in the Gasserian ganglion. The trigeminal nerve is the largest of these three; it arises from the side of the brain just beneath the cerebellum and passes forward to the ganglion. The abducens is a very slender nerve which arises from the ventral surface of the medulla near the median line. The facial and auditory nerves arise behind the trigeminal. The auditory is the larger and passes directly to the auditory capsule; the facial is much smaller and passes alongside the trigeminal to the Gasserian ganglion.

The ninth and tenth cranial nerves, the glossopharyngeal and the vagus, respectively, arise from the side of the medulla, back of the auditory nerve, by four roots. These unite to form a single nerve, which emerges from the cranial cavity by a foramen at the side of the

foramen magnum.

> Exercise:[1] Study the ventral surface of the brain. Cut the cranial nerves and remove the brain from the skull. Put it into a dish of water and study its ventral surface. Identify the olfactory lobe, the hemispheres, and the structures belonging to the diencephalon.

The optic nerves will be seen issuing from the optic chiasma, a structure formed by the crossing of the optic nerves on the ventral side of the brain. Behind the optic chiasma is the infundibulum, a large median projection which is divided into a right and a left lobe, and extending from the hinder end of which is a flattened body called the pituitary body. This body is lodged in a depression in the floor of the cranial cavity, and usually remains there after the brain is removed from the skull.

The ventral portion of the midbrain is formed by the crura cerebri, which lie beneath the optic lobe and are partly concealed by the infundibulum. Arising from the crura near the middle line may be seen the very delicate oculomotor nerves.

The medulla oblongata is but slightly wider than the spinal cord. A longitudinal groove is present in the midventral line of both.

1/Wolcott, R., op. cit. p. 376.

Exercise:[1] Draw the ventral aspect of the brain on a scale of 3".

THE MUSCULAR SYSTEM [2],[3],[4]

Most muscles in the land vertebrates are attached at both ends by means of tendons. One end is usually attached to a more or less fixed and the other to a more movable portion of the body, the former being called the origin of the muscle and the latter its insertion. The middle part of the muscle is called the belly; by its contraction the origin and insertion, and with them the skeletal pieces to which they are attached, are brought nearer together. Muscles are usually attached to the bones and cartilages; thick, fibrous membranes, called aponeuroses, which often cover muscles and other organs, may however, serve the same purpose.

Study the superficial muscles of the ventral surface of the hind leg. The longest muscle of the thigh is the sartorius. It is a long band, which extends along the middle of the thigh from the pelvis to the proximal

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1/Parker and Haswell, A Textbook of Zoology. Vol. 2. Boston: The MacMillan Co. 1940. p. 264.

2/Burnet, M., A Laboratory Manual of Zoology. New York: American Book Co. 1908. p. 95.

3/Hegner, R. W., College Zoology. New York: Harper and Bros. 1936. p. 399, et. seq.

4/Newman, H. H., Outlines of General Zoology. New York: The MacMillan Co. 1925. pp. 225-302, passim.

end of the shank. Just in front of it is a broad muscle, the vastus internus, which forms the anterior border of the thigh. It forms also the anterior portion of a threefold muscle, the triceps extensor femoris, which is the principal extensor muscle of the thigh. The other two portions of this muscle are on the upper side of the leg; they are the rectus anticus femoris and the vastus externus, the latter being posterior to the former.

Posterior to the sartorius on the ventral surface are three muscles, the adductor magnus, the rectus internus major, and the rectus internus minor, the latter of which forms the hinder margin of the thigh. These are all, together with the sartorius, flexors of the leg.

On the lower leg, or shank, the large muscle which forms the calf is the gastrocnemius. At its lower end is the tendon of Achilles, which passes over the ankle and is continued in the plantar aponeurosis, a broad, tendinous band covering the sole of the foot. The front side of the shank is formed by the tibialis anticus muscle.

Study the superficial muscles of the dorsal surface of the leg. The anterior half of the surface of the thigh is occupied by two muscles already noted, the rectus anticus femoris and the vastus externus. Posterior to the last-named muscle are the biceps femoris, the semimembranosus, and the rectus internus minor, the

latter forming the hinder margin of the leg.

On the shank will be seen the large gastrocnemius, forming the calf of the leg; the tibialis anticus, forming its anterior border; and the peroneus between the two.

THE SKELETAL SYSTEM 1/,2/,3/

This system is made up of two portions, the exoskeleton and the endoskeleton. The exoskeleton in vertebrates consists of the hardened bony or horny structures which develop in the skin and furnish an external protection to the animal. These structures are very poorly represented in the frog. The skin is naked, no bony or horny scales or other hardened integumental structures being present. The toes are also without claws. The only exoskeletal structures are the teeth and certain bones called membrane bones which form a part of the skull. These bones are, however, so intimately joined with the other bones and cartilages of the skull that they will be studied in connection with them.

1/Burnet, M., op. cit. pp. 95-96.
2/Hegner, R. W., op. cit. pp. 393-399, passim.
3/Parker and Haswell, op. cit. p. 247, et. seq.

The endoskeleton consists of the bony and cartilaginous framework of the body. It may be divided into the axial skeleton, which included the skull and the spinal column, and the appendicular skeleton, which includes the framework of the two pairs of appendages, that is, the legs and the girdles which join them with the trunk. The breastbone may also be conveniently studied with the appendicular skeleton.

THE APPENDICULAR SKELETON: The anterior appendages consist of the forelegs and the pectoral girdle. This girdle is formed of a right and a left half which meet midventrally; here they enter into a close union with the breastbone and form with it a bony and cartilaginous ring which almost completely encircles the forward part of the trunk.

Each half of the pectoral girdle supports one of the forelegs and is composed of two portions, a dorsal and a ventral portion. The former portion consists of two skeletal pieces of nearly equal size, the suprascapula and the scapula, which lie respectively on the dorsal and lateral sides of the body. The suprascapula - the dorsal half - is a broad, thin plate which extends upward over the spinal column. Its broad, free dorsal end is composed of cartilage; the remainder of it is bone. The scapula is an elongated plate of bone which extends

from the suprascapula to the ventral side of the body.

The ventral portion of the pectoral girdle consists of two bony and three cartilaginous skeletal pieces. The two bones are the coracoid and the clavicle, the former being the larger and the more posterior in position, and extending from the scapula to the mid-ventral line. Joining them is the glenoid cavity, in the hinder side of which is a depression, in which the humerus articulates.

The breastbone or sternum, lies in the medial area of the body, between the ventral ends of the two pectoral girdles, and is made up partly of bone and partly of cartilage.

Remove the pectoral girdle with the foreleg from the body. Inasmuch as it is not joined with the vertebral column it may be removed by freeing it from the muscles in which it is embedded. First locate accurately the delicate suprascapula on each side of the body. Then insert the blade of a small scalpel under the supra-scapula on one side and free it from the muscles which lie over it. Pass the knife down to the scapula and then to the ventral portion of the pectoral girdle. Do the same on the opposite side of the body. Disarticulate and remove the two forelegs and very carefully clean away the muscles.

THE FORELEG: The skeleton of the foreleg is composed of three divisions, a proximal, a middle and a distal division.

The proximal division, or upper arm, is composed of a single bone, the humerus. The head of it, which is cartilaginous, fits into the glenoid cavity and forms the shoulder joint. At the distal end is a large round projection, on each side of which is a ridge forming the articular surface for the bone of the next division.

The middle division, or forearm, is composed of a single bone, the radioulna. It is formed by the fusion of the radius and the ulna, the two bones which are present in the forearm of most vertebrates. The larger part of the bone is the radius. Its proximal end is concave, the projecting process on it being the olecranon or elbow. Its distal end has two articular surfaces.

The distal division is composed of the carpus, or wrist, and the hand. The carpal bones are six in number, arranged in two rows, a proximal and a distal row. The hand is made up of five digits, of which the first digit, or thumb, is very small and rudimentary. Each of the other four digits is composed of two parts: the metacarpus, the long proximal bone which articulates with the carpus; and the phalanges, two or three small

bones which form the finger. The thumb contains a metacarpus alone.

Exercise:[1] Draw an outline sketch of the pectoral girdle and breastbone, representing them in one plane, also the foreleg in outline, showing accurately all the bones and cartilages; label them all carefully.

THE POSTERIOR APPENDAGES: These consist of the hind legs, and the pelvic girdle which joins them with the trunk.

The pelvic girdle, like the pectoral, is composed of a right and a left half which meet ventrally and form an arch. The dorsal ends of the arch articulate with the last vertebra of the spinal column, and at its ventral end, on each side, is the acetabulum, the articular surface of the hind leg. Extending backward from the last vertebra between the two sides of the pelvic girdle is the long bone called the urostyle, which forms the hinder part of the spinal column.

Each half of the pelvic girdle is composed of two portions, a dorsal and a ventral portion. The former consists of the long, slightly arched ilium, which forms the side of the arch and articulates dorsally with the last vertebra. The ventral portion is disk-

1/Meier and Shoemaker, Essentials of Biology. Boston: Ginn and Co. 1946. p. 401.

shaped and is composed of the ventral end of the ilium, a small, triangular bone called the ischium, and a small, triangular cartilage called the pubis; the pubis is anterior to the ischium in position.

Carefully strip the muscles from the pelvic girdle, disarticulate it from the vertebral column, and remove it and the hind legs from the body. Disarticulate the legs and thoroughly clean the pelvis.

THE HIND LEG: The skeleton of this leg closely corresponds to that of the foreleg. It is made up of three divisions, a proximal, a middle, and a distal division.

The proximal division, or thigh, is composed of a single bone, the femur, the head of which fits into the acetabulum and forms the hip joint.

The middle division, or shank, is composed of a single bone, the tibiofibula. It is formed by the fusion of the tibia and the fibula, the two bones which are present in the shank of most vertebrates. The line of division between the two is very distinct.

The distal division is composed of the tarsus, or ankle, and the foot. The tarsal bones are five in number, arranged in two rows, a proximal and a distal row. The proximal row consists of two long bones, the astragalus and the calcaneum, which are united at both

ends. The latter is on the inner side of the foot and corresponds to the heel bone of the higher vertebrates. The distal row is composed of three very small bones. The foot is made up of six digits, of which one is supernumerary and rudimentary; the others are the five digits which characterize the typical vertebrate foot. The supernumerary digit is on the inner side of the foot and consists of from one to three small bones. Each of the other five is composed of two parts: the metatarsus, a long bone which articulates with the tarsus; and the phalanges, two to four smaller bones which form the toe. The first digit on the inner side of the foot corresponds to the great toe.

Exercise:[1] Draw the ventral aspect of the leg on a scale of 2", showing accurately the outlines of the bones and cartilages.

1/Curtis, Caldwell, Sherman, Everyday Biology. Boston: Ginn and Co. 1943. p. 215.

THE AXIAL SKELETON:[1/,2/,3/] The vertebral column. Strip the muscles from the back. Disarticulate the head from the trunk.

The vertebral column is composed of nine vertebrae and a long, unsegmented bone called the urostyle, which forms its posterior portion. Four regions may be distinguished in it: a cervical region, consisting of the first vertebra; a thoracolumbar region, consisting of the succeeding seven vertebrae; a sacral region, consisting of the last vertebra; and the urostyle, which represents a caudal region.

A vertebra is made up of the following parts: the centrum, or body, which is the cylindrical ventral portion; the neural arch, on the dorsal side of the centrum, which combines with it to form the neural canal in which lies the spinal cord; and the transverse processes, a pair of long lateral projections. The neural arch is made up of a pair of neural processes, which form its sides, and the median neural spine, or spinous process, which forms its roof. On the anterior

1/Burnet, M., A Laboratory Manual of Zoology. New York: American Book Co. 1908. pp. 95-96.

2/Gordon, A., An Outline of General Zoology. New York: Barnes and Noble Co. 1942. pp. 159-166, passim.

3/Hegner, R. W., College Zoology. New York: Harper and Bros. 1936. p. 363, et. seq.

surface of the neural arch is a pair of articular projections called the prezygapophyses; on the posterior surface is a pair of corresponding postzygapophyses. It is by these projections that the vertebrae are locked together. Note the difference in size in the transverse processes of the various vertebrae.

The first, or cervical, vertebra is called the atlas. It differs from the other vertebrae principally in that it has no transverse processes (although occasionally they have been found), and a thinner centrum. On its anterior surface is a pair of depressions into which fit the articular processes of the skull, the condyles. The last vertebra, or sacrum, has large, transverse processes with which the pelvic girdle articulates. On the hinder surface of the centrum is a pair of prominences which articulate with the urostyle.

CHAPTER III

SYSTEMATIC ANATOMY AND PHYSIOLOGY OUTLINES

The Digestive System

By digestion is meant the hydrolysis, or the mixing with water, of foodstuffs to simplify them in order that they may be assimilated by the body. To the biologist the term foodstuffs implies and actually includes carbohydrates, proteins and fats. These must be broken down to their fundamental form in order to permit absorbtion. Digestion, then, is the breaking down of these carbohydrates, proteins and fats, so that food material may be converted into energy and body tissue. Water and salts, on the other hand, pass through the digestive tract unchanged, and are absorbed in their original form.

The digestive changes are brought about by the action of enzymes in the digestive tract, which includes the mouth, oesophagus, stomach, and the small and large intestines. These changes are aided and abetted by the secretions of the stomach and small intestine in conjunction with the secretions of the pancreas and gall bladder.

The Anatomy and Physiology of the Digestive System 1/,2/,3/

A. The Mouth

1. Teeth and their Function
2. The Role of Sight, Smell and Thought in Digestion

B. Salivation

1. Glands
   a. Structure
   b. Innervation
   c. Causes of Secretion

C. Saliva

1. Composition
2. Function

D. Deglutition

1. Musculature
2. Innervation

1/Best and Taylor, The Physiological Basis of Medical Practice. 4th ed. rev. Baltimore: Williams and Wilkins. 1945. p. 416, et. seq.

2/Health Education. A Guide for Health Instruction. Circular #1. Boston: The City of Boston Printing Department. 1946. p. 31.

3/Lewis, W. H., Gray's Anatomy. 24th ed. rev. Philadelphia: Lea and Febiger. 1942. p. 1121, et. seq.

E. The Stomach

1. Anatomy
2. Musculature
3. Innervation
4. Movements
    a. Gastric Cycle
        (1). Empty Stomach
        (2). Full Stomach
5. Gastric Secretions
    a. Types of Cells
    b. Innervation
    c. Causes of Secretion
6. Digestion in the Stomach
7. Absorbtion from the Stomach

F. The Small Intestine

1. Musculature
2. Innervation
3. Secretion
    a. Kinds
    b. Composition
    c. Causes
4. Absorbtion from the Small Intestine

G. The Pancreas

1. Secretions
2. Enzyme Action

H. The Large Intestine

1. Movement
2. Innervation
3. Function
4. Defecation (optional)

I. The Liver

1. Hepatic Function
    a. Storage of Food Material
    b. Storage of Other Materials
    c. Manufacture of Food
    d. Manufacture of Other Materials
    e. Detoxication
2. Bile Formation
    a. Function of Bile

Suggested Problems for Discussion [1]

1. What sort of digestion takes place in the mouth, and what glands and enzymes are involved?

2. What sort of digestion takes place in the small intestine and which glands and enzymes are involved?

3. In what part of the food tube is there no digestion taking place?

4. Where is the digestion of protein started and where does it end?

5. Where does the digestion of fat start and where does it end?

6. Where does the digestion of carbohydrates start and where does it end?

7. How do absorbtion and assimilation differ?

8. Explain: Food in the small intestine is in the body but not of it.

9. How much of the food tube can be entirely dispensed with?

10. Describe the passage of food through the food tube.

11. Why can a person live for a long time solely on glucose feeding?

12. Why is alcohol classed as a food?

1/ Health Education. op. cit. Passim.

13. Give a good definition of "food".

14. What causes hunger?

15. How is heat supplied to the body? Energy?

16. What is meant by nutrition?

17. What are nutrients?

18. Explain how food is assimilated by the body.

19. What is metabolism?

20. What is malnutrition?

21. What are the classifications of food?

22. How does food get into the bloodstream?

23. What is the role of vitamins in digestion?

24. How can exercise reduce weight, and also aid persons who are underweight?

25. What is the chief cause of overweight?

Teachers' References for the Digestive System

For Demonstrations and/or Class Exercises.

Miller and Blaydes	pp. 309-326
1. Structure and Movements of the Stomach	p. 310
2. Enzyme Chart	p. 310
3. Tests for Sugar	pp. 327-325
4. Tests for Starch	p. 309
5. Data for observation of effects of Vitamins and Dietary Outline	pp. 312-316
6. Tests for Protein	p. 317

Anatomy References.

Gray's Anatomy	pp. 1121-1166
	pp. 1181-1223
Warren's Anatomy Atlas	pp. 91, 295, 298, 300, 303-309

Physiology References.

Best and Taylor	pp. 416, 423, 449, 447, 496-499
Hayden	pp. 61-71

Students' References for the Digestive System

Andress, Goldberger, Halleck. pp. 101-114

Baker, Mills, Connor. pp. 224-272

Crisp, K. pp. 157-190

Curtis, Caldwell, Sherman. pp. 302-354

Gregg and Rowell. pp. 79, 125, 133-150, 166, pp. 173-231

Gruenberg and Bingham. pp. 163-183

Kroeber, Wolff. pp. 261-289

Meier and Shoemaker. pp. 332-333 (Frog)
pp. 426-435 (Man)

Pieper, Beauchamp, Frank. pp. 51-88, 147, 564

Williams. Passim

Wilson, Bracken, Almack. pp. 95-115

The Anatomy and Physiology of the Circulatory System 1/,2/,3/

A. The Heart

1. Location
2. Size
3. Structure
4. Function
5. Nervous Control

B. The Arteries

1. Structure
2. Function
3. Role of Arteries in Blood Pressure
4. Effect of Age, Emotion, and Exercise on Arteries
5. Nervous Control

C. The Veins

1. Structure
2. Function

1/Best and Taylor, The Physiological Basis of Medical Practice. 4th ed. rev. Baltimore: Williams and Wilkins. 1945. p. 1, et. seq.

2/Health Education. A Guide for Health Instruction. Circular #1. Boston: The City of Boston Printing Department. 1946. Passim.

3/Lewis, W. H., Gray's Anatomy. 24th ed. rev. Philadelphia: Lea and Febiger. 1942 p. 519.

D. The Capillaries

1. Structure
2. Function

E. The Blood

1. Composition
    a. Red Cells
    b. White Cells
    c. Blood Platelets
2. Function
3. Blood Pressure
    a. The Nature and Determination of Blood Pressure
    b. The Use of the Stethoscope

F. Lymph

1. Composition
2. Function
3. Route

G. Divisions of the Vascular System

1. Systemic
2. Pulmonary
3. Coronary

H. Common Cardiac Diseases

1. Hypertension
2. Coronary Disease

I. Blood Clotting

1. Fibrinogen
    a. Source
    b. Function
2. Thrombin
    a. Source
    b. Function
3. Calcium
    a. Function in Blood Clotting
    b. Common Sources
    c. Calcium Deficiencies
4. Vitamin K
    a. Function
    b. Body Source
    c. Role in Vascular System
5. The Liver
    a. Role in Supplying Blood Constituents
    b. As Source of Clotting Components

Suggested Problems for Discussion [1]

1. How does heart muscle differ from other muscle types and why?

2. What happens when a blood vessel ruptures?

3. The nature of shock.

4. How is shock treated?

5. What are the leading types of heart disease?

6. Why is cardiac disease the chief cause of death?

7. What is the role of lymph in the general circulatory scheme?

8. Why is saline solution used following hemorrhage?

9. Describe the route of the blood through the heart.

10. Compare the function of the right and left hearts.

11. What is the significance of the diastolic pressure?

12. What changes occur in the blood in the various body areas?

    a. lungs
    b. heart
    c. liver
    d. intestines
    e. brain
    f. muscles - at rest and in exercise

1/ Health Education. op. cit. Passim

13. How does lymph return to the blood stream?

14. What is anemia?

15. Why are transfusions necessary?

16. What are blood groups and what is their significance?

17. What is the clotting mechanism?

18. What causes cerebral hemorrhages?

19. What is the coronary circulation?

20. What is meant by the expression "blood bank"?

21. What is coagulation?

22. How do the arteries aid in maintaining blood pressure?

23. Define: blood pressure.

24. What is the "RH" factor?

25. How does exercise affect the heart?

Teachers' References for the Circulatory System

For Demonstrations and/or Class Exercises

Miller and Blaydes	pp. 336-341
1. Structure of Blood	p. 336
2. Circulation (in Frog)	pp. 337-340
a. in web of foot	p. 337
b. in viscera	p. 337
c. in vessels	p. 339
3. Heart Beat	p. 340

N.B. Use of the Frog is recommended for these demonstrations. The text cited provides complete directions.

Anatomy References

Gray's Anatomy	pp. 519-693
1. The Blood	p. 519
2. The Heart	pp. 524-529
3. The Arteries	pp. 548-550
4. The Veins	p. 644
5. The Portal System	p. 682
6. The Lymphatics	p. 693
Warren's Anatomy Atlas	p. 275

Physiology References

Best and Taylor	pp. 1, 7, 27, 33, 61, 88, 112
Hayden	pp. 34-49

Histology Reference

Maximov and Bloom	pp. 39-269
1. Blood and Cells	pp. 39-43
2. Blood Vessels	pp. 244-265
3. Lymphatic System	pp. 267-269

Chemistry Reference

Harrow	pp. 254-276

Students' References for the Circulatory System

Andress, Goldberger, Halleck. pp. 26-57

Baker, Mills, Connor. pp. 325-328, 353-375

Crisp, K. pp. 191-212

Curtis, Caldwell, Sherman. pp. 355-379

Gregg and Rowell. pp. 205-236

Gruenberg and Bingham. pp. 185-200

Kroeber, Wolff. pp. 290-307

Meier and Shoemaker. pp. 437-448

Pieper, Beauchamp, Frank. pp. 86-94, 100, 101, 564

Williams. pp. 274-324

Wilson, Bracken, Almack. pp. 119-144

The Anatomy and Physiology of the Respiratory System 1/,2/,3/

A. The Nose
   1. Nostrils
   2. Cilia
   3. Membranes
   4. Temperature Control

B. The Throat

C. The Oesophagus
   1. Trachea

D. The Bronchi

E. The Lungs
   1. Air Sacs
   2. Pleura

F. The Role of Breathing
   1. The How of Breathing
   2. The Why of Breathing

1/Best and Taylor, op. cit. p. 279, et. seq.

2/Health Education. A Guide for Health Instruction. Circular #1. Boston: The City of Boston Printing Department. 1946. p. 39.

3/Lewis, W. H., Gray's Anatomy. 24th ed. rev. Philadelphia: Lea and Febiger. 1942. p. 1093, et. seq.

G. The Site of Gaseous Exchange

1. Internal Respiration
2. External Respiration

H. The Role of Blood in Respiration

1. The Role of Red Cells
    a. Haemoglobin
2. Effects of Anemia
    a. Types of Anemias

I. The Mechanics of Breathing

1. Muscular action
    a. Diaphragm
    b. Intercostal Muscles
2. Air Sacs
3. Pleural Capillaries

Suggested Problems for Discussion [1]

1. What is respiration?
2. What is the significance of carbon dioxide?
3. What potential danger does a broken rib present?
4. Why does poliomyelitis interfere with respiration?
5. What is the effect of altitude on respiration?
6. What is asphyxiation?
7. Diseases of the respiratory tract:
   a. Tuberculosis
   b. Asthma
   c. Hay Fever
   d. Pneumonia
   e. Common Cold
8. Artificial respiration.
9. Preventive measures in respiratory diseases.
10. Relationship between the heart and respiration.
11. What is "Second wind"?
12. Methods of transmission of respiratory diseases.

[1] Health Education. op. cit. Passim.

13. Diseases due to virus infections.

14. Is tuberculosis inherited?

15. What is the difference between a contagious and an infectious disease?

16. The role of sanitoria in tuberculosis.

17. The purpose for and the use of X-Ray in respiratory diseases.

18. How has control of diphtheria been accomplished?

19. What is the difference between internal and external respiration?

20. What occupations carry respiratory hazards?

21. How many types of pneumonia are there?

22. What are some of the newer surgical techniques in tuberculosis therapy?

23. What is meant by the term "Athletic Heart"?

24. What new drugs are used in pneumonia therapy?

25. What is the role of the thyroid in cellular respiration?

Teachers' References for the Respiratory System

For Demonstrations and/or Class Exercises

Miller and Blaydes	pp. 342-353
1. Test for CO_2	p. 341
2. CO_2 Generator	p. 264
3. Test for Oxidation	p. 343
4. Measuring the amount of CO_2 Absorbtion	pp. 343-344
5. A simple Respiration Apparatus	pp. 345-347
6. Mechanics of Human Breathing	p. 352

Anatomy References

Gray's Anatomy	pp. 1093, 1106, pp. 1113-1118
Warren's Anatomy Atlas	pp. 267-269

Physiology References

Best and Taylor	pp. 293-313; p. 342

Hayden pp. 50-60

Chemistry Reference

Harrow pp. 298-311

Students' References for
the Respiratory System

Andress, Goldberger, Halleck. pp. 58-87

Baker, Mills, Connor. pp. 311-322, 376-383

Crisp, K. pp. 227-239

Curtis, Caldwell, Sherman. pp. 380-393

Gregg and Rowell. pp. 237-263

Gruenberg and Bingham. pp. 201-213

Kroeber, Wolff. pp. 308-319

Meier and Shoemaker. pp. 397-407

Pieper, Beauchamp, Frank. pp. 67, 88-117

Williams. pp. 325-354

Wilson, Bracken, Almack. pp. 145-170

The Anatomy and Physiology of the Nervous System 1/,2/,3/

A. The Brain

1. The Cerebrum
2. The Cerebellum
3. The Pons
4. The Medulla
5. The Site and Function of each of the above

B. The Spinal Cord

1. Structure
2. Site
3. Function

C. The Nerves

1. The Cranial Nerves
2. The Spinal Nerves
   a. Structure
   b. Function
   c. Types

1/Best and Taylor, The Physiological Basis of Medical Practice. 4th ed. rev. Baltimore: Williams and Wilkins. 1945. pp. 776-936, passim.

2/Hayden, R., Elementary Hygiene, General and Naval. Annapolis: U. S. Naval Institute. 1939. pp. 24-43.

3/Health Education. A Guide for Health Instruction. Circular #1. Boston: The City of Boston Printing Department. 1946. pp. 56-57

D. The Autonomic Nervous System

1. Function
2. Value

E. The Spinal Column

1. Protective Function

a. Bony Structure
b. Membranes

2. Fluid

F. Diseases of the Nervous System

G. Special Senses

1. The Eye

a. Structure
b. Function
c. Care

2. The Ear

a. Structure
b. Function
c. Care

3. Other Senses

Suggested Problems for Discussion [1]

1. What are the functions of the brain? The spinal cord?

2. What are reflexes?

3. What is White Matter? Grey Matter?

4. Why are injuries to the spine serious? To the back of the head?

5. How does the nervous system operate with respect to the senses?

6. Why is a mastoid operation considered dangerous?

7. How do colds affect the ears?

8. How may an ear infection affect the eye?

9. How does posture affect the spinal cord?

10. Why is it that a person with a cold can neither smell or taste?

11. How do alcohol and nicotine affect the nervous system?

12. How do they affect the senses?

13. Explain: the right side of the brain controls the left side of the body and vice versa.

14. Why is a "Rabbit Punch" considered dangerous?

1/ Health Education. A Guide for Health Instruction. Circular #1. Boston: The City of Boston Printing Department. 1946. p. 50.

Suggested Problems for Discussion 1/

1. What are the functions of the brain? The spinal cord?

2. What are reflexes?

3. What is Polio Watson? Grey Matter?

4. Why are injuries to the spine serious? To the base of the head?

5. How does the nervous system operate with respect to the senses?

6. Why is a mastoid operation considered dangerous?

7. How do colds affect the ears?

8. How may an ear infection affect the eye?

9. How does posture affect the spinal cord?

10. Why is it that a person with a cold can neither smell or taste?

11. How do alcohol and nicotine affect the nervous system?

12. How do they affect the senses?

13. Explain: the right side of the brain controls the left side of the body and vice versa.

14. Why is a "Rabbit Punch" considered dangerous?

1/ Health Education. A Guide for Health Instruction. Olympia, Wash. Boston: The City of Boston Printing Department. 1949. p. 80.

15. Explain: a blow to the solar plexus may be fatal.

16. What is the function of the "Iron Lung" in poliomyelitis?

17. What is reflex action?

18. What did Pavlov's experiment demonstrate?

19. What is a conditioned reflex?

20. What are some common mental diseases?

21. What is meant by local anesthesia?

22. What does the term nystagmus mean? What does the condition derive from?

23. Define: Myopia; Astigmatism; Hyperopia.

24. What is the significance of Mastoiditis?

25. How can infected teeth affect the ears?

Teachers' References for the Nervous System

For Demonstrations and/or Class Exercises

Miller and Blaydes	pp. 363-379
1. The Pithed Frog	p. 371
2. Hind-Leg Scratch	p. 371
3. Eye and Nostril Response	p. 371
4. Nerve-Muscle Preparation	p. 372
5. Human Reflexes	p. 373
a. Iris Response	p. 373
b. Tactile Response	p. 373
c. Knee Jerk	p. 373

Anatomy References

Gray's Anatomy	pp. 745-1050
1. Neurons	pp. 745-747
2. Spinal Cord	pp. 760-767
3. Brain	pp. 775-797
4. Cranial Nerves	pp. 871-885
5. Autonomic Nervous System	pp. 989-992
6. Special Senses	pp. 1009-1010
Warren's Anatomy Atlas	pp. 46-118

Physiology References

Best and Taylor	pp. 776-936
Hayden	pp. 24-33

Histology Reference

Maximov and Bloom	pp. 180-182
1. Eye and Ear	pp. 603-640

Chemistry Reference

Harrow	pp. 532-541

Students' References for

the Nervous System

Andress, Goldberger, Halleck. pp. 126-312

Baker, Mills, Connor. pp. 495-535

Crisp, K. pp. 269-273, 441

Curtis, Caldwell, Sherman. pp. 414-450

Gregg and Rowell. pp. 62-111

Gruenberg and Bingham. pp. 273-299

Kroeber, Wolff. pp. 368-407

Meier and Shoemaker. pp. 455-470

Pieper, Beauchamp, Frank. pp. 382-394, 559-560

Williams. pp. 355-456

Wilson, Bracken, Almack. pp. 237-264

The Anatomy and Physiology of the Muscular System 1/,2/,3/

A. Muscle Types

1. Voluntary
   a. Skeletal
   b. Location
   c. Characteristics
2. Smooth
   a. Visceral
   b. Location
3. Cardiac
   a. Characteristics

B. Functions of Muscle

1. Skeletal Muscles
2. Visceral Muscles
3. Cardiac Muscle

1/Hayden, R., Elementary Hygiene, General and Naval. Annapolis: U. S. Naval Institute. 1939. pp. 13-19.

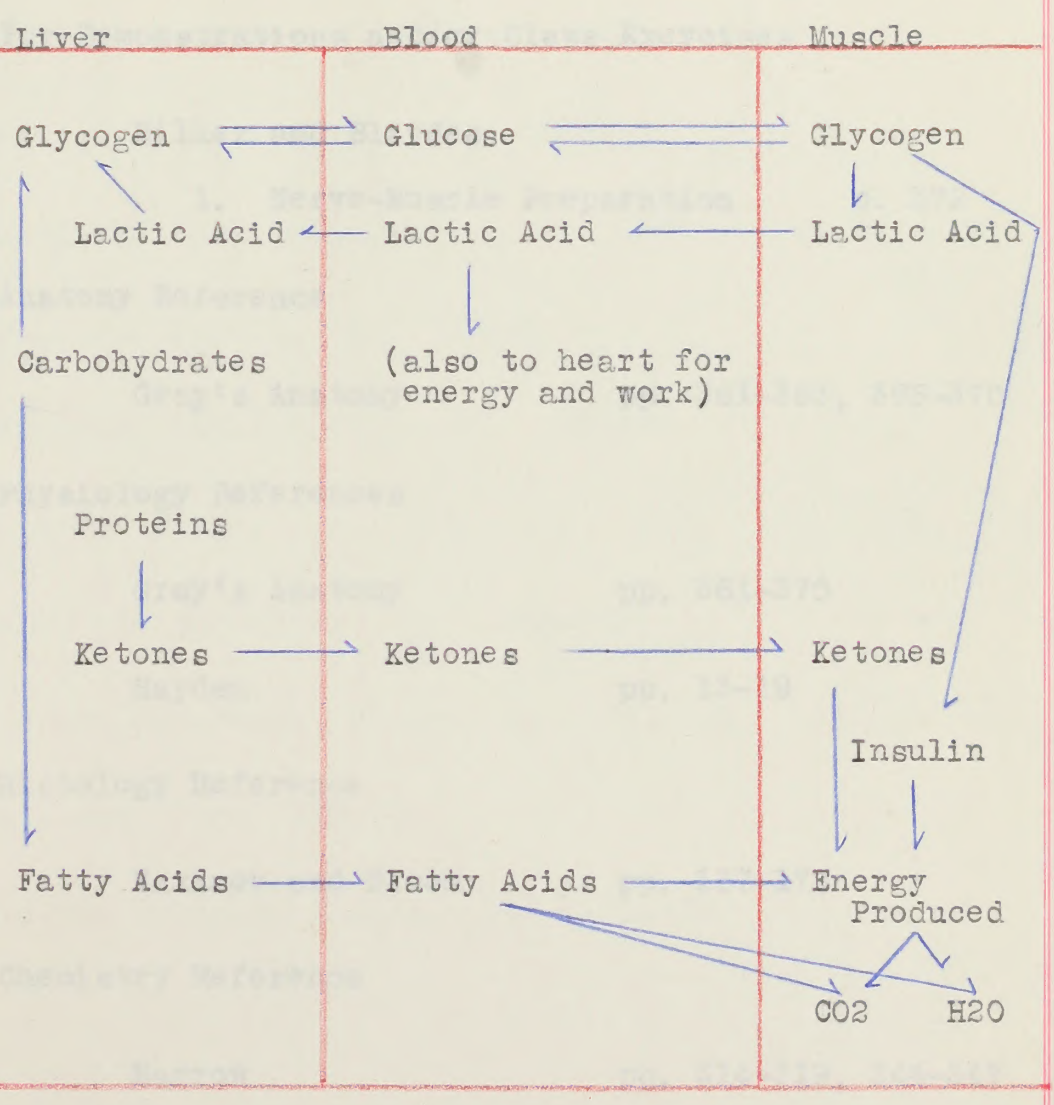
2/Health Education. A Guide for Health Instruction. Circular #1. Boston: The City of Boston Printing Department. 1946. Passim.

3/Lewis, W. H., Gray's Anatomy. 24th ed. rev. Philadelphia: Lea and Febiger. 1942. pp. 361-370.

C. Source of Muscle Energy

1. Glucose
2. Lactic Acid
3. Miscellaneous Sources of Energy
4. Waste Products of Muscle
    a. Muscle Fatigue
    b. Exercise

An Outline of the Origin and Destination of Energy Material for Heart and Muscle [1]



Carbohydrates are the food of choice for muscle energy. Lactic acid is the food of choice for heart muscle. However, ketones, fats, and proteins are used also.

1/Best and Taylor, The Physiological Basis of Medical Practice. 4th ed. rev. Baltimore: Williams and Wilkins. 1945. pp. 612-622.

Teachers' References for the Muscular System

For Demonstrations and/or Class Exercises

Miller and Blaydes

1. Nerve-Muscle Preparation p. 372

Anatomy Reference

Gray's Anatomy pp. 361-363, 365-370

Physiology References

Gray's Anatomy pp. 361-370

Hayden pp. 13-19

Histology Reference

Maximov and Bloom pp. 157-172

Chemistry Reference

Harrow pp. 314-319, 344-347

Students' References for

the Muscular System

Andress, Goldberger, Halleck. pp. 234-259

Baker, Mills, Connor. pp. 384-391

Crisp, K. pp. 240-251

Gregg and Rowell. pp. 17-41

Gruenberg and Bingham. pp. 292-294

Kroeber, Wolff. pp. 176, 310, 337, 405, 482, 561

Meier and Shoemaker. pp. 385-394

Pieper, Beauchamp, Frank. pp. 561-563

Williams. pp. 135-150

Wilson, Bracken, Almack. pp. 171-195

The Skeletal System

The skeletal system is the bony framework of the body. It serves principally to support the body, but also functions to protect the organs from injury and as an attachment for muscles. By bone is meant a hard, rigid, connective tissue, impregnated with mineral salts, the latter laid down by the osteoblasts, or bone cells. The form in which these salts are identified in bone is called intercellular substance. Hence, bone is actually both organic matter - richly supplied by arteries, veins, and nerves - and inorganic matter, in the form of mineral salts.

The Anatomy and Physiology of the Skeletal System 1/,2/,3/

A. Parts of the Skeleton

1. The Head
2. The Trunk
3. The Spinal Column
4. The Pelvis
5. The Extremities

B. Materials of the Skeleton

1. Bone
2. Cartilage
   a. Tendons
   b. Ligaments

C. Functions of the Skeleton

1. Attachment of Muscle
2. Shape of the Body
3. Protection

1/Hayden, R., Elementary Hygiene, General and Naval. Annapolis: U. S. Naval Institute. 1939. pp. 8-12.

2/Health Education. A Guide for Health Instruction. Circular #1. Boston: The City of Boston Printing Department. 1946. p. 29.

3/Lewis, W. H., Gray's Anatomy. 24th ed. rev. Philadelphia: Lea and Febiger. 1942. pp. 80-85.

D. Articulation of the Skeleton

1. Kinds and Function of Joints

a. The Neck

(1). The Atlas

b. The Vertebrae

c. The Shoulder

d. The Hip Joint

e. The Joints of the Extremities

2. Function of Tendons and Ligaments

E. Causes of Malformation of the Skeleton

1. Poor Posture

2. Diseases

a. Rickets

b. Arthritis

c. Tuberculosis

3. Glandular Disorders

Suggested Problems for Discussion[1/]

Muscular and Skeletal System

1. What is the difference between a single and a compound fracture?

2. How does a fracture differ from a break?

3. What is the structure of the spinal column?

4. What is the relationship between age and bone fractures?

5. How do diseases such as Rickets, Tuberculosis and Arthritis affect bone?

6. What types of muscle are there?

7. Where are they found?

8. How do they differ in action?

9. What is fatigue?

10. What is the effect of posture on bone and muscle development?

11. What is the role of calcium in bone development?

12. How does exercise affect muscles?

13. Relationship of posture to health.

1/Health Education. op. cit. pp. 41-42.

14. What is the structure of the feet?

15. What are some common foot disorders?

16. Basic rules for good posture.

17. Relationship of nutrition to muscular development.

18. How many bones are there in the human body?

19. What is the role of sunshine in bone development?

20. What foods help to build good bones?

21. At what age is bone development complete?

22. During which period of development is bone growth greatest?

23. Why are babies' bones less liable to fracture?

24. How does swimming promote muscular development?

25. What is the effect of poliomyelitis on muscle?

Teachers' References for the Skeletal System

Demonstrations not practicable

Anatomy References

Gray's Anatomy	pp. 80-85
Warren's Anatomy Atlas	pp. 114, 153, 162, pp. 197, 214, 265, p. 319

Physiology Reference

Hayden	pp. 8-12

Histology Reference

Maximov and Bloom	pp. 118-133
1. Cartilage	pp. 118-123
2. Bone	pp. 126-133

Chemistry Reference

Harrow	pp. 451-453

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Andress, Goldberger, Halleck. pp. 238-259

Baker, Mills, Connor. pp. 384-391

Crisp, K. pp. 240-251

Gregg and Rowell. pp. 42-61

Gruenberg and Bingham. pp. 25, 48, 98-100, 348

Kroeber, Wolff. pp. 174-176, 229, 463, 563, 716

Meier and Shoemaker. pp. 385-394

Pieper, Beauchamp, Frank. pp. 60-65, 141-143, 561

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